

Normal Oxygen Saturation Values in Pediatric Patients

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Abstract

Objectives: To determine normal oxygen saturation (OSAT) values in infants and children measured by pulse oximetry.

Methods: Infants and children admitted to a children's hospital for elective surgery from 11/20/2000 to 3/30/2002 underwent surgical clearance screens consisting of illness symptoms, vital signs and OSAT in room air. Based on the presence of respiratory infection (RI) symptoms, a "normal" patient was defined as one without respiratory symptoms and who was not scheduled for surgery involving the airway, pulmonary or cardiovascular systems (APC).

Results: Of the 3600 forms collected, 2069 were completely filled out and for elective surgery. For all age groups combined, the percent of patients undergoing APC surgery or with RI symptoms for each OSAT were as follows (OSAT: %patients APC/RI): 100%: 13%, 99%-99.5%: 15%, 98%-98.5%: 14%, 97%-97.5%: 18%, 96%-96.5%: 38%, 95%-95.5%: 29%, and <95%: 0%.

Conclusions: Although OSAT of 95% and 96% are adequate (i.e., not requiring acute oxygen therapy), these values are associated with higher rates of APC/RI involvement and thus should be considered potentially abnormal. OSAT of 97% is on the border of normal. Normal OSATs can occur with APC/RI conditions, but an OSAT less than 97% is associated with a higher risk of an APC/RI condition.

Introduction

Pulse oximetry has gained popularity as an inexpensive, noninvasive, and generally reliable means to assess oxygenation.¹ A suggested "fifth vital sign", pulse oximetry provides earlier detection of clinically occult hypoxemia by allowing continuous oxygen saturation (OSAT) measurements.² In a recent study, pulse oximetry was determined to be a simple, noninvasive screening test for congenital heart disease in asymptomatic newborns, further endorsing its utility as a test of overall health.³ Data indicate that many physicians may not recognize moderate oxygen desaturation in some pediatric cases, and that pulse oximetry in these situations may provide important information that affects medical treatment.⁴

Despite its importance and widespread acceptance, the precise interpretation of pulse oximetry readings

has not yet been clearly defined. "Normal" pediatric oxygen saturation values are inconsistent between sources. For example, normal arterial oxygen saturation values have been reported as 94-99%⁵, 95-97%⁶, and greater than 95%⁷ by three different textbooks.

Considering the widespread reliance on pulse oximetry, as well as the lingering uncertainty over its precise interpretation, the purpose of this study is to more clearly define "normal" oxygen saturation values in pediatric patients (i.e., the oxygen saturation among normal children).

Methods

Infants and children admitted to a children's hospital for elective surgery from 11/20/2000 to 3/30/2002 underwent routine surgical clearance screening assessments consisting of illness symptoms (rash, fever, cough, wheezing, nasal congestion, vomiting, diarrhea, etc.), infectious disease exposure, nursing physical assessment, vital signs and OSAT in room air. These measurements were obtained in the emergency department by an emergency department nurse. The standard of nursing practice is to record reliable OSAT measurements which are steady, reproducible, with a steady perfusion bar or wave form signal. Copies of these clearance forms were saved as separate records in a "surgical clearance binder". These forms were reviewed by study investigators and the above information was recorded in a spreadsheet. The actual patient charts were not reviewed in most instances.

Most of these values should be indicative of OSAT values in healthy children because elective surgery is generally performed in children of stable health status. Of the 3600 forms collected, only those involving patients with elective surgical procedures were included (i.e., unscheduled, emergency surgical procedures were excluded), leaving 2127 forms. Forms with missing or illegible information were further researched through the hospital's computer system and medical records. Fifty-eight forms remained incomplete following this additional research, leaving a final total of 2069 forms included in the study.

A "normal" patient was defined as one without respiratory infection (RI) symptoms (nasal congestion, coughing, wheezing) on the clearance screening

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Table 1.— Oxygen Saturation Values in Non APC/RI and APC/RI Children

	Oxygen Saturation (%)							
	100	99, 99.5	98, 98.5	97, 97.5	96, 96.5	95, 95.5	<95	total
< 1 yr (n=333)								
Non APC/RI	199	48	33	11	4	0	0	295
Patients with APC/RI	24 (11%)	6 (11%)	2 (6%)	4 (27%)	1 (20%)	1 (100%)	0	38 (11%)
1-5 yr (n=897)								
Non APC/RI	475	162	84	28	3	4	3	759
Patients with APC/RI	78 (14%)	30 (16%)	19 (18%)	6 (17%)	4 (57%)	1 (20%)	0	138 (15%)
6-19 yr (n=839)								
Non APC/RI	414	174	112	25	1	1	2	729
Patients with APC/RI	59 (14%)	32 (18%)	15 (13%)	4 (16%)	0	0	0	110 (15%)
All (n=2069)								
Non APC/RI	1088	384	229	64	8	5	5	1783
Patients with APC/RI	161 (13%)	68 (15%)	36 (14%)	14 (18%)	5 (38%)	2 (29%)	0	286 (14%)

assessment and who was not scheduled for surgery involving the airway, pulmonary or cardiovascular systems (APC). In some instances, the OSAT value recorded by nurses were two numbers such as “97%-98%”. In such cases, this value was analyzed as the mean between these two numbers (e.g., 97.5%).

Patients were categorized as “normal” (defined above as non-APC/RI) and those with RI and/or APC findings. This categorization was then cross tabulated using various cutoff levels of oxygen saturation (e.g., <98% versus >98%) to determine which cutoff value has the greatest degree of distinguishing the non-APC/RI patients from the APC/RI patients.

This study was approved by the hospital institutional review board.

Results

The distribution of oxygen saturation values among APC/RI and non-APC RI patients are shown in Table 1. All p values are doubled sided probabilities.

For patients under 12 months of age, APC/RI percentages were significantly higher in those with OSATs less than 98% (29% vs 10%, $p=0.011$). For patients in the 1 to 5 year age group, the APC/RI percentages in those with OSATs less than 97% and those greater than or equal to 97% were 33% vs 15% ($p=0.052$, not significant for a double sided hypothesis, but significant for a single sided hypothesis). For the combined patient group less than 6 years old, APC/RI percentages were significantly higher in those with OSATs <98% (24% vs 14%, $p=0.014$) and in those with OSATs <97% (33% vs 14%, $p=0.012$).

For patients 6-19 years old, only 4 out of 839 presented with oxygen saturations of <97%. As a whole (0-19 years), the APC/RI percentages were significantly higher in those with OSATs less than 98% (19% vs. 13%, $p=0.048$) and in those with OSATs less than 97% (28% vs. 14%, $p=0.039$).

Discussion

Ideally, a study to determine normal OSAT values should be done by measuring the oxygen saturation on a large group of healthy children and then measuring the oxygen saturation on a large group of children with respiratory infections and conditions involving the airway and cardiopulmonary systems. The OSAT values of the normal group should form a skewed distribution near 100%. The

distribution would not be bell shaped because of the maximum limit value of 100%. Among the group of children with airway and cardiopulmonary conditions, the distribution of OSAT values will be broader (less of a peak) since many of them will have normal oxygen saturations and some of them will have abnormal values. At some cutoff oxygen saturation value, the frequency of this value among the normal group is very low, while it is moderately frequent in the airway and cardiopulmonary group. This value, most likely represents the borderline of what the expected oxygen saturation for a normal child should be.

The study methodology described attempts to use this concept with the limitation, that the patients are not chosen. Rather, this is a large cohort of patients undergoing elective surgery. Most of these children are normal, but some of them have documented respiratory symptoms and/or conditions involving the airway, pulmonary or cardiovascular system. This latter group of children (those with RI and/or APC conditions) defines the abnormal group. While this study design is not perfect, it does provide some data toward defining an abnormal OSAT value. Without this data and further data attempting to define the normal range, textbooks will continue to publish normal ranges based on a paucity of data.

The number of older children with low OSAT values (<97%) was very low. It is possible that older children are easier to assess by parents and physicians. Thus, it might be easier to determine that they might be having some respiratory compromise and are less likely to schedule elective surgery. Alternatively, they might be more tolerant of their elective surgical condition and thus, they are better able to wait for a more ideal surgical date when their respiratory status is optimal.

In the younger age groups, oxygen saturation values of 96% to 94% were more common than that found in the group of older children. It is unlikely to conjecture that this occurs because physicians believe that younger children tolerate hypoxemia during surgery better than older children. More likely explanations are that younger children are more difficult to assess, or that younger children have a greater need or priority for elective surgery procedures such that physicians would be more tolerant of respiratory symptoms to clear them for the surgical procedure that they need.

In children under 6 years of age, the percentage of APC/RI conditions is similar in OSAT levels from 98% to 100% suggesting that these values are “normal”. At OSAT levels of less than 97%, the

APC/RI percentages increase significantly suggesting that these OSAT values are not normal. An OSAT value of 97% appears to be borderline. Although oxygen saturations of 95% and 96% are adequate (i.e. do not require acute oxygen therapy), our data indicate that these values are associated with higher APC/RI percentages and should be considered abnormal.

For children and adolescents ages 6-19, only 4 out of 839 patients presented with oxygen saturations of <97%. A similar type of statistical analysis to compare the APC/RI percentages in patients above and below certain values was not possible. However, the APC/RI percentages were similar to the rates in the younger children for all OSAT values from 100% to 97%, implying that these values in this age range are also normal.

A limitation of this study is the small number of patients who presented with OSATs less than 98% (103; 6% of total patients). Another limitation is the definition of "normal" and "abnormal". This study used the presence of an APC/RI condition to classify patients as those more likely to have a condition leading to hypoxemia, most often due to ventilation perfusion mismatch (VQM). Patients without respiratory infection symptoms and without airway, pulmonary, and cardiac problems are unlikely to be hypoxemic and are unlikely to have significant VQM. In our study, a patient could have had an APC condition and we would not have known about this. For example, if a patient with congenital heart disease arrives for a scheduled hernia repair, if they had no RI symptoms and the history of congenital heart disease was not written on the clearance form, study investigators reviewing the form would not have been able to classify the patient as one who has an APC condition. Thus, some non-APC/RI patients might have the potential for VQM, but this likelihood is much lower in the non-APC/RI group compared to the APC/RI group. In this study, non-APC/RI does NOT indicate that the patient is normal. However, this does serve as a useful control group which should have a substantially lower risk of VQM compared to the APC/RI group. If the percentage of APC/RI patients (i.e., abnormal patients) suddenly increases at a particular OSAT level, this suggests that this OSAT level is abnormal.

Although a future study could measure OSAT values during well child checks to further define this, office and clinic pediatric nurses are less experienced in identifying potentially hypoxemic patients compared to ED nurses who perform pulse oximetry measurements on ill patients more frequently. Additionally, since nearly all of these children would be normal, such a study would similarly suffer from a small number of patients with OSAT values of 97% or less.

The utilization of defining a normal OSAT value in clinical practice is to identify occult VQ mismatch. For example, an OSAT value of 95% with physical exam findings suggestive of an upper respiratory infection, should raise the suspicion of occult VQM. Since it is unlikely that a respiratory infection limited

to the upper airways alone, would adversely affect oxygenation, common causes of VQM such as pneumonia and asthma should be considered. Unfortunately, OSAT can vary with other factors such as body position, medications, etc. OSAT measurements will often vary even in the absence of factors known to affect the OSAT. It is difficult to conclude that a difference of 1% could be clinically important. However, a normal range must somehow be defined with an understanding that there might be values of uncertainty at the fringe of this normal range.

In summary, although OSAT of 95% and 96% are adequate, these values are associated with higher APC/RI percentages and thus should be considered potentially abnormal. An OSAT of 97% is on the border of normal. Normal OSATs can occur with APC/RI conditions, but an OSAT less than 97% is associated with a higher risk of an APC/RI condition.

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